

ELEMENTS OF LOGISTIC SUSTAINABILITY IN TACTICAL OPERATIONS WITH NATIONAL AND MULTINATIONAL PARTICIPATION

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ABSTRACT

Logistical sustainability at the tactical level represents the ability of manoeuvre units to maintain the flow of essential resources – such as rations, ammunition, fuel, and equipment – under varying operational pressures, losses, and distances, thereby ensuring continuity and efficiency in both offensive and defensive operations. This article proposes a simplified mathematical model based on the R–A–L–T variables (Resources, Adaptability, Losses, Time) to assess logistical sustainability in complex tactical scenarios. The study integrates NATO doctrinal analysis, Just-in-Time principles, and emerging technologies to optimize supply flows. The methodology is based on a case study using hypothetical data focused on two tactical combat units, for which logistical variables are quantified along primary and secondary lines of effort. The results are compared and interpreted to highlight differences in sustainability between defensive and offensive operations. The study provides a scientific basis for planning and conducting integrated tactical operations while ensuring continuous and adaptable logistical support in order to achieve the desired end state.

KEYWORDS: tactical operations, tactical operational logistics, logistical sustainability, mathematical model, logistical flows

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1. Introducere

Evolved military operations are characterized by high complexity, dynamism, and interdependence among tactical, joint, and logistical support components. In today's operational environment – dominated by volatility, uncertainty, threats, and hybrid actions – logistical sustainability is no longer a peripheral element of combined operations. Instead, it is a decisive factor for freedom of action and the success of tactical-level operations, whether conducted at national or multinational scale (Kress, 2016; Minculete, 2025).

The planning and execution of simultaneous defensive and offensive operations on multiple fronts by a mechanized brigade integrated into a multinational force highlight the need for a rigorous, adaptable analytical framework. Such a framework must explain how logistical flows directly influence maneuver units during the execution phases of planned operations. In particular, operations conducted along primary and secondary axes generate distinct logistical requirements, depending on battle intensity, terrain characteristics, vulnerability of supply lines, and variability of losses. To assess these differences in a

reproducible and comparable manner, this study implements a simplified mathematical model based on R–A–L–T variables (Resources, Adaptability, Losses, Transport Time), integrated with NATO doctrinal analysis (AJP-3.2, 2022; APP-28, 2024; AJP-4, 2025).

A practical example involves a tactical battalion operating in a contested environment with constrained supply routes and rapidly changing conditions. Decisions regarding resource allocation, timing, and the integration of emerging technologies – such as unmanned aerial systems – can critically determine whether operational objectives are achieved efficiently or delayed. This scenario underscores the essential role of sustainable logistical planning at the tactical level and demonstrates the practical application of the R–A–L–T framework, where drones primarily enhance *Adaptability* (A) and, in specific cases, reduce *Transport Time* (T).

The aforementioned example reveals that logistical sustainability is becoming a quantifiable indicator, useful for both tactical operation planning (through OPLANs) and managing their execution (through OPORDs), in accordance with evolving operational requirements. In the current context, characterized by the proliferation of emerging technologies and autonomous logistics solutions – such as

ground and air transport drones – the analysis must consider their impact on operational mobility, force protection and resource efficiency, in addition to improving Adaptability and reducing Transport Time for Just-in-Time replenishment.

Through the conceptual structure developed in this article, I sought to highlight clarity and coherence in defining the objectives, methods and practical applications. Table no. 1 summarizes the research scope, from my point of view, the directions of investigation, the research questions and the applied methods, providing an integrated framework for applying theoretical concepts in realistic tactical scenarios. Using this structure, the study connects NATO doctrinal analysis with the mathematical model R–A–L–T (Resources, Adaptability, Losses, Transport Time) and the assessment of logistical sustainability in maneuver operations. In particular, it highlights how emerging technologies – such as unmanned aerial systems – affect adaptability and transport time, linking theory to actionable decision-making. This approach supports the interpretation of the results and allows the formulation of practical recommendations for effective planning, operational leadership and the integration of advanced logistics solutions in tactical environments.

Table no. 1
Conceptual structure of scientific research

Component	Scientifically developed content
Research purpose	Developing a rigorous analytical framework for assessing the sustainability of logistical flows at the tactical level, using the R-A-L-T (Resources, Adaptability, Losses, Transport Time) model, to compare the baseline data of logistical sustainability between defensive and offensive tactical operations conducted on primary and secondary directions. The study aims to integrate emerging technologies (land and air logistics drones) into Just-in-Time logistics, optimize OPLAN/OPORD processes, and substantiate tactical decisions in a predictive and implementable manner.
Research directions	1. Theoretical and doctrinal analysis of logistical sustainability in tactical land operations, according to NATO doctrinal provisions. 2. Operationalization of the R-A-L-T (Resources, Adaptability, Losses, Transport Time) mathematical model by defining evaluation criteria and quantification metrics. 3. Validation of the model through a relevant case study on two mechanized battalions engaged in defensive and offensive operations on main and secondary directions, including autonomous logistical technologies.

Component	Scientifically developed content
Research questions	1. How can the R-A-L-T (Resources, Adaptability, Losses, Transport Time) variables be quantified for assessing logistical sustainability? 2. What are the differences between logistical sustainability in defensive versus offensive operations? 3. What role do the main and secondary directions play in configuring logistical flows at the tactical level? 4. To what extent can logistical adaptability (A) and emerging technologies compensate for losses (P) and transport time (T) at the tactical level? 5. What implications do the results have on planning and execution through OPLAN and OPORD, as well as on the logistical flows of a unit or large tactical unit?
Research methods	1. Comparative documentary and doctrinal analysis at the tactical level. 2. Mathematical modeling of logistical sustainability in tactical operations. 3. Simulation of defensive and offensive tactical scenarios. 4. Comparative analysis by directions of operation at the tactical level. 5. Integrated Logistic Assessment.

Contemporary tactical military operations, with national and/or multinational status, require not only mobility and flexibility, but also a high capacity to adapt logistical flows to the variability of the operational environment. In this context, logistical sustainability becomes a critical indicator of the efficiency of units and large units, directly influencing the continuity of actions, the speed of reaction and resilience in the face of losses or long transport distances. By quantifying the available resources, logistical adaptability, losses and time, the R-A-L-T (Resources, Adaptability, Losses, Transport Time) model allows for the systematic and comparable analysis of logistical performance, providing a solid basis for tactical decision-making.

In a complex tactical scenario, which includes a defensive operation on the main and secondary directions, as well as an offensive operation to encircle the enemy forces, the differences between logistical flows become significant. Secondary directions, usually less exposed to enemy pressure, allow for the optimization of resource distribution, while the main directions require logistical mechanisms for rapid compensation of losses. The integration of emerging technologies, such as land and air transport logistics drones, and the application of the Just-in-Time principle allow for increased adaptability and reduced vulnerability of supply lines, thus contributing to maintaining the sustainability of tactical operations in all directions.

This research, by combining the R-A-L-T (Resources, Adaptability, Losses, Transport Time) mathematical model with doctrinal analysis and revealing a tactical scenario with hypothetical data, aims to provide both theoretical foundation and practical recommendations for commanders. By comparative assessment of logistical sustainability in defensive and offensive operations at the tactical level, the study highlights the mechanisms through which logistical adaptability and the use of modern technologies can compensate for operational pressures, supporting the planning, execution and achievement of the final state of the mission. The results thus provide an applicable framework for both tactical operations training and planning, and for the development of agile logistics doctrine in tactical land forces with national and multinational status (Lopez, 2024).

In the research process, the methodological approach is mixed, as it combines theoretical-doctrinal analysis with mathematical modeling and case study. The method of documentary analysis is applied to relevant NATO doctrines and specialized literature in the field of military logistics, for the conceptual substantiation of logistical sustainability at the tactical level. Mathematical modeling is used to develop a simplified model for evaluating logistical sustainability, based on the R-A-L-T (Resources, Adaptability, Losses, Time), variables allowing the quantification of the relationships between resource flows and

operational constraints. The case study, built on hypothetical data, is applied to two tactical combat units, in order to compare the levels of logistical sustainability on the main and secondary directions of action, both in defensive and offensive operations. The comparative method and interpretative analysis of the results allow highlighting the impact of losses, time and adaptability on the continuity of logistical support, contributing to validating the applicability of the proposed model in complex tactical scenarios.

2. Sustainability of Tactical Operational Logistics in the High-Intensity Armed Conflict in Ukraine

The high-intensity armed conflict in Ukraine has brought back to the forefront the decisive role of operational logistics as a determinant of the combat capability and resilience of tactical forces engaged in a highly evolved war of attrition. Beyond the strictly tactical dimension of armed confrontations, the dynamics of operations highlight the fact that maintaining the continuity of logistical flows, protecting critical infrastructures, and adapting supply chains (distribution) to new technological threats are essential conditions for supporting the combat effort in the medium and long term (Genini, 2025; Sharma, 2023).

In this operational framework, the sustainability of logistics at the tactical level can no longer be treated as an auxiliary function of the force, but must be conceptualized as an integrated, interdependent system, in a direct functional relationship with maneuver, firepower and command and control processes. The experience of the armed conflict in Ukraine highlights the fact that logistical dysfunctions generate systemic effects, manifested by the loss of operational initiative, the decrease in the pace of military actions and the increase in the vulnerability of the combat device, regardless of the degree of technical equipment or the numerical superiority of the

forces engaged (Allied Command Transformation, 2023; Center for Strategic and International Studies/CSIS, 2023).

Analyzing the sustainability of tactical operational logistics in this conflict requires a multidimensional approach, based on the examination of deeply interdependent variables. These include the vulnerability of supply and distribution networks in an environment characterized by persistent surveillance and high-precision strike capabilities, the influence of emerging technologies on the protection, mobility and operation of logistics systems, the degree of dependence on external support and the requirements of multinational interoperability, as well as the doctrinal and organizational adaptations generated by the prolonged and high-intensity nature of tactical military operations (Mohammed et al., 2023).

One of the most significant operational lessons identified in the high-intensity armed conflict in Ukraine consists of the systematic exposure of the logistics infrastructure to kinetic and non-kinetic actions carried out in the depth of the device. Communication axes, railway junctions, ammunition depots and maintenance facilities have been integrated into the list of priority objectives, which has led to the blurring of the classic distinction between the front line and the operational space in depth. Persistent surveillance carried out by unmanned aerial vehicles and space-based sensors, correlated with precision strikes executed by long-range artillery systems and missiles, has transformed tactical operational logistics into a permanently contested domain, in which sustainability is conditioned not only by production and transportation capacity, but also by the ability to reduce the logistical footprint, to disperse resources and to avoid their detection and destruction by enemy forces (Watling & Reynolds, 2023).

At the same time, the massive consumption of ammunition and fuel, specific to high-intensity operations, exerted

unprecedented pressure on resupply systems. The pace of artillery fire, in particular, highlighted the limits of national stocks and imposed a continuous logistical effort, difficult to sustain exclusively through internal resources. This reality amplified Ukraine's dependence on external support, transforming logistics into a phenomenon with a pronounced strategic and politico-military dimension (Hamilton, 2025).

The integration of international logistical support has also generated significant challenges. The diversity of weapons systems and technical standards has required rapid adaptations in the areas of maintenance, personnel training and spare parts management. Without a high level of interoperability and coordination, external logistical flows risk becoming inefficient or even generating operational bottlenecks (AJP 4, 2025). In this regard, the conflict in Ukraine highlights the need for an integrated approach to logistics, in which multinational cooperation is supported by standardization and common procedures.

Against the background of these constraints, the adaptation of tactical operational logistics has required a profound reconfiguration of the planning and execution mode. The dispersion of depots, the fragmentation of transport convoys (columns), the use of multiple routes and the increase in the mobility of logistical structures have become essential measures to reduce vulnerability to attacks. At the same time, the active protection of logistics, including through anti-drone means and electronic warfare measures, has gained an importance comparable to that of the protection of tactical combat forces (Christensen & Renic, 2024; Toubman et al., 2025).

Another defining element of sustainability is the digitalization of military logistics in general and at the tactical level in particular. Resource management systems, real-time monitoring of flows and the use of predictive analysis tools allow for the optimization of

consumption and the anticipation of needs depending on the evolution of the tactical situation. In a conflict characterized by uncertainty and accelerated pace, these capabilities increase the response capacity and contribute to maintaining operational continuity (Pawelczyk, 2018). A hypothetical disruption of a key logistical IT node – for example, a temporary failure in the battalion's supply tracking system – demonstrates the dual advantage of digitalization: real-time visibility of alternative supply routes and rapid adjustment of delivery schedules. This scenario highlights how digital solutions can mitigate the operational impact of cyber risks while maintaining logistical sustainability.

In conclusion, the high-intensity armed conflict in Ukraine demonstrates unequivocally that the sustainability of tactical operational logistics is a critical factor in military success. Logistics cannot be treated as a secondary function; it must be organically integrated into the planning and execution of operations. The lessons learned from this conflict indicate that future military structures will need to develop flexible, dispersed, digitized, and deeply interoperable logistics systems capable of operating effectively in a contested, highly volatile environment. In the absence of such an approach, even the most capable combat forces risk losing their operational capability before achieving their planned objectives.

3. Methodology

To analyze the impact of hybrid threats on the conduct of tactical actions, the present study uses a case study with hypothetical data, aiming to evaluate the operational behavior and logistical sustainability of two maneuver battalions, one engaged in defense and the other in the offensive, in a complex tactical scenario. This approach is appropriate at the tactical level, where the interaction between decision, maneuver, and logistical support is directly and measurably manifested (Kress, 2016).

In the security environment characterized by the manifestation of hybrid threats, the battalion deployed in defense structures its action based on a set of adaptive measures designed to ensure the resilience of the combat system, maintain a coherent situational picture and exercise functional control over an operational space in which conventional and unconventional means act simultaneously. This approach corresponds to the multidimensional nature of hybrid warfare, defined in the specialized literature as a form of conflict that integrates military and non-military instruments into a unitary operational framework (Hoffman, 2007; Romandash, 2025). By correlating the reaction to kinetic threats with measures to counter informational and operational pressures, the battalion aims to reduce local vulnerabilities and protect critical points, adopting a flexible decision-making process capable of simultaneously managing multiple forms of pressure exerted by the adversary (Chirilă, 2025).

In an operational framework dominated by the hybrid logic of conflict, the battalion engaged in the offensive is forced to go beyond the paradigm of exclusively conventional tactical maneuver, permanently integrating measures to respond to cyber, informational actions and other non-military influences that can affect the cohesion of the force and the pace of advance. The specialized literature highlights that hybrid warfare involves the coordinated use of classical armed force, irregular tactics, and non-military instruments in a unique and dynamic confrontation space (Hoffman, 2009; Mészáros & Țoca, 2023). In this context, offensive units are forced to adapt their tactical decisions in real time, increase their organizational flexibility, and preserve the initiative, reacting promptly to informational and cyber disruptions, without compromising the achievement of the main operational objective.

In this complex framework, operational military logistics at the tactical level emerges

as a determining factor in the success of combat forces, especially in the context of non-linear and simultaneous actions. Allied doctrine emphasizes that logistical sustainability is an essential condition for maintaining combat capability and continuity of operations, regardless of the type of mission. The dynamic nature of modern conflicts, combined with the pressure on resources and the vulnerability of supply lines, amplifies the importance of optimizing logistical flows at the tactical level.

On this basis, in the present study I propose to comparatively evaluate the logistical sustainability of two maneuver battalions by applying the Just-in-Time concept, adapted to the specific requirements of the military domain, and by integrating modern technologies, such as land and air transport capabilities and unmanned aerial systems. Within the R–A–L–T (Resources, Adaptability, Losses, Transport Time) framework, the use of unmanned aerial systems primarily improves Adaptability (A) by improving situational awareness and flexibility of supply routes, while in specific applications – such as aerial resupply – it also contributes to reducing Time (T). To maintain the transparency of the model, this analysis attributes drones mainly to the Adaptability variable, with secondary effects on Time considered contextual. In this regard, the Methodology integrates a mathematical model of sustainability with quantitative analysis of key logistical variables, providing an objective and practical framework for tactical-level research.

3.1. Mathematical Model of Logistical Sustainability in Tactical Operations with National and Multinational Status

To assess the sustainability of logistical flows in tactical operations, a simplified mathematical model can be used, which correlates the main logistical variables with the resultant S, of interest in determining the sustainability of each

operation. The model allows for the objective quantification of the interactions between resources, adaptability, losses, and transport time, in accordance with doctrinal standards (Friedrich & Gump, 2014; Mehrjerdi & Lotfi, 2019)

$$S = \frac{R \cdot A}{L + T}$$

where:

- ✓ **S** = logistical sustainability of the tactical operation;
- ✓ **R** = available resources (individual combat rations; ammunition, fuel, equipment, etc.);
- ✓ **A** = adaptability/reconfigurable logistics;
- ✓ **L** = losses caused by attacks or deficiencies;
- ✓ **T** = transport time (from the execution logistics structure to the tactical subunit or unit).

In analyzing logistical sustainability at the tactical level, it is essential to identify and structure the critical variables that determine the operational capability of operationally engaged tactical units (from the organic of a large maneuver unit). Logistic sustainability (S) is not a one-dimensional concept; it depends on the available resources (R), the ability to adapt and reconfigure logistics (A), and losses caused by adverse actions or internal deficiencies (L). In an intensely contested operational environment, such as that demonstrated by the conflict in Ukraine, the interaction between these variables defines the operational pace, the resilience of supply chains, and the ability to maintain the tactical initiative. Table no. 2 summarizes the operational definitions, examples, and impact of each variable on the logistical sustainability of tactical operations.

Table no. 2
Variables of the tactical operational logistics sustainability model

Symbol	Variable	Operational definition	Relevant content/examples	Impact on tactical operation
S	Logistic sustainability of the tactical operation	The capacity of the logistics system to continuously and adequately provide the resources necessary to maintain the combat capability of the forces engaged during the tactical operation	Continuity of resupply; resilience of logistics chains; protection and redundancy of routes; regeneration capacity	Determines tactical operational pace, maintaining initiative, and sustaining maneuver and firepower
R	Available resources	The totality of logistical resources at the disposal of the force, expressed quantitatively and qualitatively, necessary for the conduct of tactical operations	Individual combat rations; ammunition; fuel; water; equipment; spare parts; means of transport	Directly influences the duration of the tactical operation, the intensity of fire, and the autonomy of subunits and units
A	Adaptability / reconfigurable logistics	The ability of the logistics system to quickly adapt to changing tactical situations, threats and losses, through redistribution, dispersal and modification of logistics flows	Alternative routes; dispersed depots; fragmented convoys; use of transport logistics drones; JIT replenishment	Allows for increased operational resilience and reduces vulnerability to kinetic and non-kinetic actions
L	Logistic losses	Reduction of resources or logistical capacity at the tactical level caused by enemy attacks, accidents, planning errors, or organizational deficiencies	Destruction of warehouses; losses in transport columns; degradation of military and civilian infrastructure; technical failures	It implies a decrease in sustainability (S), which affects the pace of the operation and increases the risk of losing the action initiative

Note: In conceptual modeling, S can be interpreted as a function dependent on R, A and L, where adaptability (A) acts as a compensating factor and losses (L) represent the main element of degradation of tactical logistic sustainability.

(Source: AJP-4 2025; FM 4-0, 2024)

Determining the transport time (T) at the tactical level is a critical element in assessing logistical sustainability and in planning operations. This parameter reflects the speed with which the necessary resources (fuel, ammunition, equipment and individual rations) can be brought to combat units, thus influencing the pace of maneuver and the ability to react to developments in the field. The data summarized in Table no. 3 provide essential information on distances,

available means of transportation, terrain conditions and congestion or vulnerability factors, all of which constitute determining variables for calculating and optimizing transport time at the tactical level. The analysis of these data allows the identification of critical points in the logistics chain and the substantiation of decisions regarding the reconfiguration of adequate resupply flows to ensure the continuity of tactical operations (defensive and/or offensive).

Table no. 3
Stages of determining transportation time (T) in tactical logistics planning

Nr criteria	Stage	Main content	Reference elements analyzed
1.	Establishing tactical distance	Determining the actual route between the departure point and destination	Effective distance, detours, checkpoints, alternative routes
2.	Identification of the means of transport	Selecting the appropriate means of transport for the mission	Transport type, capacity, average tactical speed
3.	Terrain and infrastructure evaluation	Analysis of travel conditions on the chosen route	Road conditions, relief, weather conditions, speed reduction coefficients
4.	Tactical situation analysis	Assessing risks and tactical constraints	Threat level, escort, night travel, planned stops
5.	Calculation of travel time (T)	Determination of the effective travel time	$T = D/V_{med.Ta.}$, where: D = tactical distance; $V_{med.Ta.}$ = average tactical speed
6.	Adding auxiliary times	Complementing travel time with additional operational times	Loading/unloading, convoy formation, stops, refueling, incidents
7.	Validation of the estimate	Confirmation of the realism of the total estimated time	SOPs, exercises, historical data, operational experience, assessment (evaluation) made by S4/G4

Note: Table developed based on NATO doctrines and military logistics support and transport manuals, which describes the stages of determining transport time at the tactical level, from establishing distance and selecting means of transport to validating the final estimate

(Source: ADP 4-0, 2019; FM 4-01, 2014)

The values of the variables are expressed numerically based on the logistical assessment, estimates and concretizations through OPLANs and OPORDs, according to NATO doctrinal principles (AJP-3.2, 2022; APP-28, 2024; AJP-4, 2025).

3.2. Hypothetical Configuration of the Tactical Action Scenario

3.2.1. Operational Context

Offensive and defensive operations with national and multinational status are planned, coordinated and conducted under conditions appropriate to the protection of

forces, in phases according to OPLANs, and executions are carried out in accordance with OPORDs and benefiting from Just-in-Time logistical support, to ensure the continuity of resources and achieve the final state of the mission.

From a scientific perspective, phased planning allows for the continuous assessment of logistical flows and the adjustment of resources according to the evolution of each tactical situation. In defensive operations, this methodology optimizes the positioning of critical resources, reducing the vulnerability of units and increasing resilience to losses. In offensive operations, phased planning facilitates the synchronization of encirclement movements with the rapid redistribution of resources to the directions of maximum pressure, maintaining the logistical sustainability of each attack against enemy forces.

At the same time, the implementation of Just-in-Time logistical support, through the use of traditional armored means of transport, ensures the rapid delivery of equipment and materials, as well as critical goods (ammunition, medicine, combat rations, etc.) with the help of land and air transport logistics drones – necessary in emergency situations for first-echelon subunits. This combination of phased planning and modern transport technologies increases the adaptability of logistical flows,

reduces reaction time and minimizes the risk of resource depletion under conditions of increased operational effort, thus validating the applicability of the mathematical model of logistical sustainability (Christensen & Renic, 2024).

3.2.2. Detailed Analysis of Tactical Logistics Variables

The key variables R, A, L, T (Resources, Adaptability, Losses, Transport Time) reflect the ability to maintain logistics flows in the main and secondary directions, in defensive and offensive scenarios. To ensure logistics flows, standard replenishments are carried out with armored wheeled and tracked vehicles, which allow the protection of resources in exposed areas. In urgent situations, for the rapid provision of critical materials to subunits and units in the first echelon (such as: ammunition; medicines; combat rations, etc.), land and air transport logistics drones are used, which allows increasing the adaptability of flows and reducing delivery times. The hypothetical values of the variables for each direction are presented in Table no. 4 and provide the basis for the analysis of logistics sustainability (Vrysagotis et al., 2017), highlighting the combined impact of available resources, operational logistics adaptability, anticipated losses and transportation time on the S indicator.

Table no. 4
The values of the logistic variables for the main and secondary directions of battalions A and B

Battalion	Direction	R	A	L	T	S
A	Main	130	1,0	18	60	0,12
A	Secondary	110	1,25	7	35	0,357
B	Main	100	1,3	20	50	0,13
B	Secondary	90	1,35	10	40	0,27

3.3. Adequate Analysis of the Results Obtained

The analysis of the values of S (sustainability of tactical operations) for the two maneuver battalions, operating in the main and secondary directions, clearly shows the relationship between logistics variables and operational performance.

The secondary directions recorded higher sustainability values ($S = 0.27-0.357$), which can be explained by a reduction in losses (P) and a higher operational logistics adaptability (A). The increased adaptability reflects the ability to quickly reconfigure logistical flows, either by committing resources or by adjusting Just-in-Time deliveries, which ensures operational continuity even in difficult conditions. Transport times (T) are shorter or more efficiently managed, which reduces the risk of resource depletion and maintains stable logistical flows.

The main directions, with low sustainability values ($S = 0.12-0.13$), involve extended distances and higher losses, which generates pressures on high tactical logistical support. Under these conditions, traditional flows are insufficiently adaptable, and the lack of flexibility reduces the ability to maintain the resources necessary for real-time operations.

The impact of ground and air transport logistics drones is relevant from a scientific perspective: these platforms increase adaptability (A) through rapid deliveries and flexible rerouting, significantly reducing transport time (T). Thus, an increase in global sustainability S is achieved, which allows continuous logistical support in all directions, including in areas with limited access or exposed to enemy attacks. This approach aligns with NATO principles on agile and sustainable logistics (FM 4-0, 2024; FM 4-01, 2014).

Based on the determined values of S sustainability, it is observed that the

differences between the main and secondary directions are not only quantitative, but also qualitative in terms of tactical logistics performance. Secondary directions, through high values of S, allow not only maintaining essential flows, but also creating an operational buffer for rapid reaction to unexpected events, such as unforeseen losses or transport blockages. This indicates that operations planning must explicitly consider the important role of secondary flows in the distribution of resources and the protection of the main lines of support for ongoing operations.

The differences between the S values related to the main and secondary directions highlight the importance of logistical adaptability as a determining factor of tactical operational resilience. While the main directions are more vulnerable to logistical losses and extensions, the ability to reroute and quickly reconfigure flows, including through the use of logistic transport drones, partially compensates for these vulnerabilities. Thus, S values reflect not only the available resources, but also the quality of the logistics system in terms of flexibility, anticipation and reaction capacity, providing a tool for predictive assessment of the performance of tactical combat units.

The integration of emerging technologies, such as land and air transport logistics drones, produces a multiplier effect on the sustainability of tactical operations, by reducing transport times and personnel exposure to direct risks. This increase in the S indicator allows each tactical commander to plan the redistribution of resources in real time, prioritize operational objectives and maintain continuity of operations on both directions of action. From a scientific perspective, this confirms the validity of the R-A-L-T (Resources, Adaptability, Losses, Transport Time) model as a decision support tool for advanced tactical

logistics and alignment with NATO principles regarding agile and sustainable logistical support (Friedrich & Gump, 2014; Hamilton, 2025).

3.4. Benchmarking and Operational Implications

The quantitative and qualitative analysis of the logistical flows necessary to accomplish missions and achieve the final state, embodied in Table no. 4, indicates a series of critical conclusions for the planning and management of tactical operations. The values of logistical sustainability (S) highlighted in the table confirm the significant differences between the main and secondary directions, as well as the determining role of the adaptability of logistical support and terrain characteristics in maintaining resource flows in accordance with operational requirements.

The flexibility of logistical flows and the application of the Just-in-Time principle can allow achieving the final state of the mission of each tactical combat unit, even in conditions of intensive action, significant losses or large operational distances. This would reveal the ability of the logistical

systems in the composition of the action structures to quickly adapt to variations in tactical situations, to adjust routes and to optimally redistribute resources, thus ensuring the continuity of tactical operations in critical situations.

The peculiarities of the secondary directions reveal higher values of sustainability (S) (highlighted in Table no. 5), due to a favorable combination of lower provided combat forces, lower losses, moderate tactical distances and the possibility of increased adaptability. Consequently, the planning and execution of operations must integrate the analysis of secondary flows to maintain a balance between enemy pressure and resource availability, increasing the resilience of the logistics subsystem actionable here.

Emerging technologies – such as ground and air transport logistics drones – not only increase the rapid reaction capacity, but also reduce the risks associated with losses and delays in transport. From a scientific perspective, these autonomous systems contribute to a significant increase in the sustainability indicator S, even in complex and dynamic scenarios.

Table no. 5

Comparative assessment of logistical sustainability for the two battalions

Battalion	Direction	S (sustainability)	Scientific interpretation
A	Main	0,12	The low sustainability value reflects a tactical environment characterized by intense enemy actions, a dominant defensive operational profile, and exposure to significant losses. Extended transportation distances and only moderate logistical adaptability limit Just-in-Time flows, increasing the likelihood of logistical discontinuities. This value indicates the need to strengthen logistical mobility and use autonomous platforms to reduce critical delays.
A	Secondary	0,357	The high level of sustainability is due to a low volume of losses, lower tactical pressure, and higher logistical adaptability. Logistic flows are stable, and moderate distances allow for the efficient use of resources, including armored vehicles and ground and air logistics drones. The secondary direction becomes a logistical vector, capable of providing operational continuity even in critical phases of defense.

Battalion	Direction	S (sustainability)	Scientific interpretation
B	Main	0,13	The moderately low sustainability stems from the high demands of the offensive, which assume an accelerated operational pace, exposed to losses and rapid consumption of resources. Although the logistical adaptability is high, the considerable distances and density of maneuver actions make it difficult to stabilize logistical flows. The main direction requires additional logistical support, possible through land robotic platforms and regional redistribution of resources.
B	Secondary	0,27	The higher sustainability value indicates high logistical efficiency in an offensive environment, which confirms the role of (higher) logistical adaptability in reducing reaction times. The secondary direction benefits from lower losses and limited distances, favoring the maintenance of a continuous logistical flow. This becomes a favorable direction for exploitation, allowing to support the main offensive effort or to take over resources in situations of overload of the main direction.

Comparatively, the secondary directions of both maneuver battalions demonstrate higher values of logistical sustainability, which suggests that tactical operations planning must emphasize adaptability, optimal maneuver distances and minimizing losses to maximize the efficiency of the logistics flows carried out. The use of advanced and flexible transport technologies (land and air) will further increase the rapid reaction capacity and maintain critical resources in the tactical first echelon.

Therefore, the analysis of the results shows that operational sustainability depends not only on the quantity of resources, but also on the quality of logistical adaptability, loss management and transport efficiency, providing a solid basis for future action planning at the tactical level.

4. Discussions

Logistical sustainability at the tactical level should be understood as a systemic property of the operational support architecture, arising from the interaction between resources, decision-making processes, and environmental constraints. It is not limited to maintaining material flows; it reflects the logistics system's capacity to

support the pace and intensity of tactical actions throughout an operation, even under conditions of uncertainty and operational pressure. In national operations, full control over supply and distribution chains allows a direct correlation between tactical requirements and available logistics capabilities. However, this autonomy is relative, being determined by the robustness of infrastructure, the degree of technical and material modernization, and the elasticity of available resources.

From this perspective, assessing sustainability extends beyond the continuity of resupply, encompassing the functional resilience of the tactical logistics system in the face of disruptions, operational risks, and the progressive degradation of support conditions. The ability to absorb shocks and recover quickly becomes a critical indicator of logistics performance.

In multinational operations, logistical sustainability gains an additional dimension due to the doctrinal, technological, and procedural diversity of participating actors. Here, interoperability is not only a technical requirement but a structural condition for coherent functioning of logistical chains. Harmonization of standards, synchronization of processes, and elimination of redundancies

are operational imperatives; without them, dysfunctions arise that directly impact tactical support capacity. At the same time, geopolitical factors, hybrid threats, hostile actions on communication lines, and the specifics of command and control systems introduce further constraints, requiring advanced coordination mechanisms and logistics designs oriented toward flexibility and redundancy.

A key determinant of sustainability is the *adaptive nature of logistical planning*. Estimating tactical parameters – such as transport times or resource consumption – must occur within a dynamic framework capable of integrating continuous operational variations. Advanced modeling and simulation tools facilitate anticipation of risk scenarios, identification of systemic vulnerabilities, and optimization of resource allocation. Predictive approaches, coupled with adaptive response mechanisms, are essential for maintaining logistical functionality in environments characterized by volatility and high operational stress.

The accelerated development of digital technologies and automation of logistics processes has significantly redefined the sustainability paradigm. Integrated logistics management information systems improve visibility, coherence, and decision-making speed at the tactical level. At the same time, increased reliance on digital infrastructures introduces cyber vulnerabilities with potentially disruptive effects, which must be systematically addressed through cybersecurity measures embedded within the logistics architecture – a dimension often underrepresented in theoretical approaches.

Overall, logistical sustainability in tactical operations – whether national or multinational – emerges as a complex phenomenon resulting from the interaction of autonomous capabilities, collaborative mechanisms, analytical rigor, and operational flexibility. Performance directly depends on military structures' ability to simultaneously manage systemic

complexity and environmental variability through an integrated, resilient, and secure logistics system.

5. Research Limitations

The assessment of logistical sustainability in tactical operations is deeply influenced by the structural uncertainty of the operational environment, generated by the continuous variability of the terrain, weather conditions and the spectrum of adversary threats. In this context, logistical models, even based on robust doctrinal frameworks, remain analytical approximations that cannot fully capture the real configuration of material, informational and temporal flows in conditions of dynamic confrontation.

In the case of multinational operations, the issue of determining sustainability is amplified by the doctrinal, technological and organizational heterogeneity of the participating forces. Disparities in procedures, operating standards and levels of capability affect the coherence of logistical chains and limit functional interoperability.

As a result, the principles of sustainability cannot be applied uniformly, requiring continuous adjustments to the logistical architecture, with direct effects on the predictability, stability and efficiency of the replenishment and distribution processes. Strict security and confidentiality requirements impose limited access to real operational data, which restricts the possibilities for the empirical validation and calibration of the theoretical models used in logistics sustainability analysis.

Although the digitalization of processes and the use of integrated information systems increase the transparency and monitoring capacity of logistics flows, they simultaneously introduce systemic risks associated with the dependence on digital infrastructures and exposure to cyber threats. Thus, operational advantages are counterbalanced by vulnerabilities with the

potential to disrupt the continuity of logistical support at the tactical level.

In a complementary manner, the human and organizational dimensions exert a significant influence on the effectiveness of the implementation of logistical decisions. Cultural differences, political constraints, divergences in priorities and distinct resource management styles can generate institutional friction and resistance to change, affecting the resilience and performance of supply and distribution chains, especially within multinational arrangements.

Overall, these limitations highlight the complex and multidimensional nature of logistical sustainability in tactical operations and the need to adopt flexible, adaptive and integrated analytical and operational approaches. Only through mechanisms capable of responding rapidly to emerging disruptions and managing systemic interdependencies can logistical support capacity be optimized in an operational environment characterized by volatility and uncertainty.

6. Conclusions

Logistic sustainability in tactical operations is configured as a dynamic property of the support system, resulting from the complex interaction between resources, decision-making processes and operational constraints. The analysis highlights the fact that maintaining the support capacity does not depend exclusively on the continuity of resupply flows, but on the robustness and adaptability of the logistics architecture in relation to the uncertainty and volatility of the tactical environment.

Within tactical operations of a national nature, autonomy over logistics chains allows a direct correlation between operational requirements and available capacities, but the efficiency of this relationship is conditioned by infrastructural limitations, the level of technical and material capabilities and the system's capacity to absorb unforeseen

disturbances. In this context, logistical sustainability is determined by the functional resilience of critical chains and the capacity for rapid reconfiguration of resource flows.

In multinational tactical operations, logistical sustainability takes on an emergent character, being dependent on procedural and technological interoperability, convergence of standards and the efficiency of inter-institutional coordination mechanisms. Doctrinal and technical divergences introduce operational frictions that can affect the stability and predictability of logistical flows, imposing the need for command and control structures capable of ensuring redundancy, flexibility and coherence in the distribution of resources.

The analytical operationalization of logistical processes, through the metric configuration of transport times, auxiliary durations and storage capacities, constitutes an indispensable tool for assessing sustainability at the tactical level. Mathematical models and scenario simulations facilitate the anticipation of systemic vulnerabilities and the substantiation of resource allocation decisions, but their relevance is conditioned by the quality of the data and the ability to reflect the real dynamics of the operational environment. In this sense, the uncertainty associated with exogenous variables requires the integration of predictive approaches with adaptive decision-making mechanisms and operational feedback loops.

Finally, logistical sustainability cannot be conceptualized as a static state, but as an evolutionary process, governed by the interdependence between autonomous and collaborative capabilities, the level of technological integration and systemic resilience. The capacity of military structures to simultaneously manage operational complexity and the variability of the tactical environment, through an integrated, secure and adaptive logistics system, is a fundamental determinant of the effectiveness of tactical operations, both in national and multinational settings.

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